Environmental Science and Pollution Research (2023) 30:2233–2246
https://doi.org/10.1007/s11356-022-22338-9

RESEARCH ARTICLE

The determinants of life expectancy and environmental degradation in Pakistan: evidence from ARDL bounds test approach

Muhammad Azam[1] · Ijaz Uddin[1] · Najia Saqib[2]

Received: 11 April 2022 / Accepted: 28 July 2022 / Published online: 5 August 2022

Abstract
The current study aims to investigate factors affecting life expectancy in Pakistan with a special focus on environmental degradation measured by carbon emissions (CO_2 emissions) on life expectancy from 1975 to 2020. The unit root test results show mixed order integration in the series. The bound *F*-test and Johansen cointegration test confirm the long-run association between the variables. The long-run estimates of autoregressive distributive lag (ARDL) reveal that CO_2 emissions, inflation rate, food production index, and death rate have negative effects on the life expectancy, implying that life expectancy shorten when CO_2 increases, while per capita income, urbanization, population growth, birth rate, health expenditure, and education have positive effects on life expectancy, indicating that these factors prolong life expectancy. Moreover, the short-run estimates of ARDL reveal that food production index, urbanization, birth rate, infant mortality rate, and education have positive effects on the life expectancy, while inflation, per capita income, population growth rate, death rate, health expenditure, and CO_2 emissions have negative effects on the life expectancy. The findings of the study suggest that the management authorities need to regulate carbon emissions in order to prolong life expectancy which is a key determinant of the economic growth.

Keywords Life expectancy · Environmental degradation · ARDL · Pakistan

Introduction

Life expectancy is regarded as an essential indication of a country's populations public health, and it has also been frequently used by world agencies as a general gauge of the country's national development (UNDP 2010). Furthermore, the health profile is essential in defining well-being, and the life expectancy is important to determine the quality of life (Lind 2021). Gross disparities in the life expectancy within and between nations provide a serious challenge to the international community, which has regained renewed and broader significance because of the increased political and public concern (Marmot 2005). Life expectancy is defined as the average number of years predicted to reach this age. The life expectancy or the level of living in modern cultures is considered as vital, the longer a country's population lives, the more evolved the society becomes (WHO 2014). Therefore, the life expectancy is one of the most significant health indicators that influence economic development and societal well-being (Azam and Ahmed 2015; Crimmins and Zhang 2019; Azam 2019; Azam et al. 2019). Furthermore, human and social assets may be built on a solid foundation of the life expectancy. Azam and Awan (2022) noted that sound human health is undeniably a key input for sustainable economic development and prosperity. A healthy labor force certifies higher productivity and, subsequently, higher per head income.

Several recent studies have identified that environmental degradation or CO_2 emissions is also an important determinant of the life expectancy (see Murthy et al. 2021; Mahalik et al. 2022; Rahman et al. 2022). According to the World

Responsible Editor: Arshian Sharif

✉ Ijaz Uddin
ijazuddin01@gmail.com

Muhammad Azam
drazam75@yahoo.com

Najia Saqib
dr.najiasaqib@gmail.com; nsaqib@psu.edu.sa

1 Department of Economics, Faculty of Business and Economics, Abdul Wali Khan University Mardan, Mardan, Pakistan

2 Department of Finance, College of Business Administration, Prince Sultan University, Riyadh, Saudi Arabia

Health Organization (2018), in 2016 global air pollution caused 4.2 million premature deaths, and this number is expected to rise since nine out of ten people live in the areas with unsafe air quality. Environmental deterioration may harm people's health in various ways. Severe air pollution is linked to an increase in chronic illnesses (for instance lung cancer, heart disease, and asthma) and premature deaths (Pope et al. 2009). Previous research has also found that environmental deterioration increases the ecosystem unpredictability, growing the chances of droughts and floods (Haines et al. 2006). Furthermore, as a result of environmental degradation, significant fluctuations in food production and water quality may occur, contributing to increased mortality, especially among infants and the elderly, along with increase in the vulnerable persons from worse socioeconomic backgrounds. Majeed and Ozturk (2020) found that nations with greater levels of environmental degradation had higher newborn mortality rates and vice versa. Many developing countries ignores the required significant environmental actions. The emerging countries set a lot of pressure on the natural resources (such as water, land, and forests) to achieve faster economic growth, and their increased output results in the larger CO_2 emissions and industrial wastes (Raffin and Seegmuller 2014; Kasman and Duman 2015; Sapkota and Bastola 2017).

In the health's determinants literature, various macroeconomic variables are found to have an impact on health outcomes through different channels. Health indicators, also known as health outcomes, are used to assess a population's health. Health outcomes are connected to changes in the health that occur as a consequence of measurements or particular healthcare investments or treatments (CIHI 2016). Indicators of health outcomes include life expectancy, underfive mortality rate, maternal mortality rate, and many others. Although health care can be funded in a variety of ways, including public (government spending and public insurance schemes) and private (individual and household out-of-pocket payments, expenditure by non-governmental organizations, and expenditure by other private organizations), public health financing demonstrates the government's commitment to making healthcare accessible and affordable to its citizens. The government's expenditure on health is commonly used to assure health finance, and it may be categorized into recurring and capital expenditures on health. The government's funding on health care has been regularly used in the literature to explain the health outcomes (Bayati et al. 2013; Sede and Ohemeng 2015). The phenomenon of inflation is most often accompanied with an increase in the inclusive price level, lowering the buying power of money. As a result, inflation has an impact on health outcomes by increasing the cost of health care. A high rate of inflation raises the charges of healthcare services, medications, and other health inputs, limiting access to these treatments owing to an inability to pay. This leads to a lack of use of accessible health facilities and services, increasing patronage of quacks, a low level of life, and poor nutrition, among other things, all of which contribute to high death rates. Consumer price index (CPI) and GDP deflator are some of the ways to quantify inflation. Inflation has been used to explain differences in health outcomes by many researchers (Bourne 2009; Imoughele et al. 2014).

Fayissa and Gutema (2008) established a negative association between health expenditure and life expectancy in Sub-Saharan Africa by utilizing the theoretical model proposed by Grossman (1972) and used the random effect regression approach for empirical analysis. Literacy rate, food availability and per capita, decreased alcohol usage, increased urbanization, and lower carbon dioxide emissions, on the other hand, all showed a positive link with the life expectancy. They emphasized to implement prudent policies that impose the marginal efficiency of health services to enhance health outcomes. Bayat et al. (2013) investigated the determinants of life expectancy in the Eastern Mediterranean Region by using GDP per capita, health spending, food production index, employment ratio, education index, measles vaccine coverage rate, urbanization, and carbon dioxide emission as explanatory variables (EMR). They found that GDP per capita, food availability, employment ratio, education, and urbanization had a positive effect on life expectancy, whereas health expenditure, measles, immunization coverage rate, and carbon dioxide emissions had no significant relationship with life expectancy. The health production function was estimated by using the panel data for 21 EMR countries using a fixed-effect model in that study.

In the study Nasreen et al. (2012) explored the effect of wealth disparity on the health of Pakistani people's and explored that if this effect is influenced by the country's institutional framework. The study was conducted on the data from 1973 to 2010 using the cointegration and error correction model and discovered that uneven income distribution had a negative impact on people's health resulting in lowering the life expectancy and increasing the infant mortality rate. However, by establishing an effective institutional system in Pakistan, that detrimental effect might be mitigated. Ali and Audi (2016) studied the impact of income disparity, environmental deterioration, and globalization on Pakistani life expectancy from 1980 to 2015, and their findings imply that wealth disparity and environmental deterioration have a negative impact on the life expectancy. Furthermore, globalization has a favorable influence on Pakistan's life expectancy. Salehnia et al. (2022) found that CO_2 emissions and the democratic process have a negative impact on all the quantiles of life expectancy and that GDP has a negative impact on all the quantiles, although the effects of government service delivery, other liquids consumption, and petroleum showed positive effect on life expectancy in all the quintiles. Rahman et al. (2022) suggested that economic growth has a beneficial effect on the life expectancy. In the sample nations, environmental deterioration is seen as a concern, but health expenditure, clean water, and better sanitation have a beneficial impact on life expectancy. Murthy et al. (2021) used data from 1992 to 2017, to measure the impact of CO_2 emissions on life expectancy in the D-8 nations (Turkey, Iran, Malaysia, Pakistan, Egypt, Nigeria, Bangladesh, and Indonesia). The findings revealed that the economic expansion, population growth, and health spending, all have a great and beneficial impact on the life expectancy. However, CO_2 emissions showed a considerable and detrimental impact. In Pakistan, Wang et al. (2020) looked at the impact of rising nonrenewable energy use (oil, gas, and coal) pollution, death rates in the context of economic growth, and two frequent illnesses, measles, and TB. They observed that nonrenewable energy (oil, gas, and coal) raises air pollution, as well as the spread of diseases like measles and TB, and so increases mortality.

The central objective of this study is to analyze the impact of economic, demographic, and health related factors which are economic (i.e., inflation, per capita income, education, health expenditure, and food production index), demographic (i.e., education, urbanization, and population growth), and health determinants (i.e., birth rate, death rate, and infant mortality rate) on the life expectancy in Pakistan. To the best of the authors' knowledge, no study has examined the portfolio of regressors in the context of Pakistan as investigated by this study. Thus, this study contribution are two folds: firstly, this study combines all economic, environmental, demographic, and health determinants of the life expectancy for Pakistan, not explored by the previous researcher. Secondly, this study is an attempt to contribute to policy understandings for the accomplishment of sustainable development (including health sustainability) with reference to Pakistan. Empirical findings of the present study certainly help the management authorities to develop a pollution observing system and bolster environmental laws and policies in Pakistan.

The remainder of this article is organized as follows: "Review of literature" section presents prior theoretical and empirical reviews. "Data description, model construction, and empirical methodology" section deals with the data and empirical methodology. "Discussion on empirical results" section interprets the results. Finally, "Conclusion and policy recommendations" section deals with conclusions of the study.

Review of literature

Grossman's (1972) depiction of a perfect health model is useful for hypothesizing about the process of health creation. Individuals are taken into account as health makers via they make judgments regarding their practices and whether or not to undertake therapeutic or medical therapy. Lifespans are virtually unaffected as a result of this technique. Budgetary constraints, pattern advantages of the social and cultural contexts, as well as physical and mental health are all factors to be considered and the settings they entail are all causes why people are obligated to construct health in their possibilities. The theoretical health production function proposed by Grossman (1972) is based on the idea that health is determined by a variety of factors, some of which may be induced by the individual, meaning that health can be generated. Secondly, health is classified as a consumption good since it affects people's utility functions. After all, utility rises in optimum health conditions and as an investment commodity because it is a determinant of the total amount of time available for productive activities that generate income or wealth. To account for the disparity between health as an outcome and medical care as one of numerous inputs into its production, the theoretical home health production function was established. The health production function as "a function that describes the relationship between combinations of medical and non-medical inputs and the resulting output," and depicts a scenario in which an individual or government produces his or her health (outcome/output) by combining health inputs, which could include a variety of medical and non-medical variables (Wagstaff 1986). The health production function also connects these inputs to outputs, demonstrating how much health may be obtained "from a given quantity of health input, for a given degree of technical knowledge." The Grossman (1972) model can be deciphered as follows:

$$y = f(X) \tag{1}$$

In Eq. 1, y is the life expectancy, and X is a vector of diverse inputs to the health production function, including economic, environmental, health, and educational factors. Grossman suggests using the provided model to examine the life expectancy at the micro-level; nevertheless, the X is a vector of variables that may be divided into four categories by Fayissa and Gutema (2005a).

Garfield (1997) examined the health component and found that even when healthcare commodities were not included in the penalties band, negative implications for health infrastructure might arise.

The rise in the whole trading cost products and inputs has an indirect effect. The second factor has to do with government healthcare spending. Since government expenditure is reliant on tax revenue, a drop in tax revenue, along with total economic output, limits government resources and requires governments to cut expenditure on public health services. The third factor has to do with higher import costs and manufacturing costs. Private health services are still available, but at a greater cost, limiting entree to health care for a segment of the population. People who are excluded are frequently low-income and vulnerable. According to Garfield (1997), women and children are the populations most exposed to the detrimental impacts of economic sanctions on the life expectancy. The fourth argument is that the degradation of public infrastructure, particularly the sanitation system, may allow infectious illnesses to spread. Fifth, a lower wage encourages employees to take employment with difficult or harmful working conditions. Sanctions have a negative impact on health in general since they have an impact on citizens' earnings.

Burke et al. (2015) showed that unfavorable financial shocks can account for up to 20% of HIV prevalence disparities between African nations. Kim (2019) also investigated the link between sanctions and the higher prevalence of infection with HIV in women. As income falls, but so does expenditure on food and clean water, both of which have a demonstrable effect on health. In brief, economic penalties have diverse effects on various socioeconomic groups, with the poor, children, women, and the elderly bearing the brunt of the consequences (Peksen 2011; Allen and Lektzian 2013). World Health Organisation (2019) proposed that sanitation is the most important cause of life expectancy. Poor sanitation leads to the spread of illnesses for instance typhoid, hepatitis A, diarrhea, cholera, and others, all of which reduce the life expectancy. According to this data, inadequate sanitation causes roughly 432,000 deaths per year. Similarly, filthy or polluted drinking water transmits a variety of illnesses which have adverse effect on the life expectancy through infant mortality (Alemu 2017).

Menon-Johansson (2005) examined health and good governance in 199 countries and concluded that better governance via more physicians, better availability of water, and more fair economic distribution improves the health and life expectancy. The empirical findings of Fayissa and Gutema (2005b) showed that lower illiteracy and higher food accessibility index are highly associated with the increased life expectancy during delivery; however, health consumption had a strong negative connection with the life expectancy in 33 SSA countries from 1990 to 2000. Balan and Jaba (2011) revealed that uneducated population, total available readers, total beds in hospitals, and population positively effect the life expectancy while determining factor negative impacted on the life expectancy in Romania from 1970 to 2008. Ali and Ahmad (2014) found that food production has a strong connection with the life expectancy, whereas school enrollment and population development have a significant connection with life expectancy in the Sultanate of Oman from 1970 to 2012. Razzak et al. (2015) found a strong positive effects of health expenditure, gross national income, a healthy life, and good governance on the life expectancy in 40 Asian economies. Life expectancy, in contrast, is negatively connected to infant mortality rate, death rate, and the birth rate. The findings of Felice et al. (2016) study revealed that GDP per capita enhance the life expectancy in Italy and Spain from 1961 to 2008. Emamgholipour and Asemane (2016) concluded that the increasing education and health expenses reduced child death in 27 OECD countries between 1996 and 2012. Wang et al. (2020) found that excessive energy use has a negative influence on the life expectancy as well as the economic growth (Saqib 2018, 2022b). Coal, oil, and gas are Pakistan's principal energy sources, all of which are harmful to the environment and diminish life expectancy from 1972 to 2017. In their study, Yang et al. (2022a, b) observed that in Beijing City, China, environmental variables like air pollution and green land area are thought to be more effective than socioeconomic ones in determining the life expectancy from 2000 to 2018. The results of Salehnia et al. (2022) study demonstrated that CO_2 emissions and the democratic process have a negative influence on the life expectancy in all quantiles, whereas GDP has a negative impact in all quantiles except 0.95 from 2000 to 2018. Mahalik et al. (2022) found a negative relationship between life expectancy and CO_2 emissions in 68 emerging developing countries from 1990 to 2017.

The existing literature indicate that there are no or limited studies on the determinants of life expectancy with the particular focus of carbon emissions as a determinant of life expectancy, which need more exploration.

Data description, model construction, and empirical methodology

Data and variables

To examine the factors affecting the life expectancy in Pakistan with a special focus on carbon emissions (CO_2 emissions) on the life expectancy from 1975 to 2020. The data has been obtained from the World Development Indicators (WDI), latest survey (see Table 1).

Model construction

To explore the factors affecting life expectancy in Pakistan with a special focus on CO_2 emissions, we specified the following multivariate regression model which was also used by many erstwhile studies (Fayissa and Gutema 2008; Ali and Ahmad 2014; Razzak et al. 2015; Razzaq et al. 2020; Razzaq et al. 2021a, b; Saqib 2022a; Saqib 2022c; Felice et al. 2016; Wang et al. 2022; Salehnia et al. 2022; Mahalik et al. 2022; Yang et al. 2022a, b; Zhang et al. 2022; Sharif et al. 2022), and can be expressed as:

$$LEX_t = \beta_0 + \beta_1 CO_{2t} + \beta_2 PCI_t + \beta_3 FPI_t + \beta_4 POPG_t + \beta_5 BR_t + \beta_6 DR_t + \beta_7 IMR_t + \beta_8 HE_t + \beta_9 INF_t + \beta_{10} EDU_t + \mu_t \quad (2a)$$

In Eq. 2a, *LEX*, CO_2, *PCI*, *FPI*, *POPG*, *BR*, *DR*, *IMF*, *HE*, *INF*, and *EDU* represent life expectancy, carbon emissions, per capita income, food production index, population growth, birth rate, death rate, infant mortality rate, inflation, and education, respectively, and μ_t = error term, the subscript ($t = 1 \ldots\ldots\ldots t$) indicates the period. The β_0 is the intercept, while $\beta_1 \text{to} \beta_{11}$ are the slope of the respective independent variables. To overcome the problem of data sharpness and heteroscedasticity, we transformed the data into logarithm (see Hossain 2011; Zafar et al. 2021).

Pesaran et al. (2001) developed the autoregressive distribution lag technique (ARDL) as a cointegration test to confirm the long-run relationship between the variables. In comparison to traditional methods, the ARDL approach provides significant advantages. This method yields reliable estimates in all stationary situations, including I(0) or I(1), and mixed order. Equation (4) may be shown using ARDL in the following way:

$$\begin{aligned}\Delta LnLEX_t = {} & \beta_0 + \beta_1 LnLEX_{t-1} + \beta_2 LnCO_{2t-1} + \beta_3 LnPCI_{t-1} + \beta_4 LnPOPG_{t-1} + \beta_5 LnBR_{t-1} + \\ & \beta_6 LnDR_{t-1} + \beta_7 LnIMR_{t-1} + \beta_8 LnHE_{t-1} + \beta_9 LnINF_{t-1} + \beta_{10} LnEDU_{t-1} + \\ & \sum_{i=1}^{P} \alpha_1 \Delta LnLEX_{t-1} + \sum_{i=0}^{P} \alpha_2 \Delta LnCO_{2,t-1} + \sum_{i=0}^{P} \alpha_3 \Delta LnPCI_{t-1} + \sum_{i=0}^{P} \alpha_4 \Delta LnPOPG_{t-1} + \\ & \sum_{i=0}^{P} \alpha_5 \Delta LnBR_{t-1} + \sum_{i=0}^{P} \alpha_6 \Delta LnDR_{t-1} + \sum_{i=0}^{P} \alpha_7 \Delta LnIMR_{t-1} + \sum_{i=0}^{P} \alpha_8 \Delta LnHE_{t-1} + \\ & \sum_{i=0}^{P} \alpha_9 \Delta LnINF_{t-1} + \sum_{i=0}^{P} \alpha_{10} \Delta LnEDU_{t-1} + \mu_t\end{aligned} \quad (2b)$$

Using Eq. 2b, the null hypothesis is as follows: $H_0 : \beta_1 \text{to} \beta_{10} = 0$.

Econometric strategy

Augmented Dickey-Fuller (ADF) test

The augmented Dickey-Fuller (ADF) is a test which is used by Dickey and Fuller (1979) to estimate the relationship of the stationary feature. The ADF (augmented Dickey-Fuller) test is based on the following equation:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \sum_{j=1}^{k} d_j \Delta Y_{t-j} + \epsilon_t \quad (3)$$

In Eq. 3, Δ is first difference operator, Y_t is the dependent variable, the subscript *t* represents the time series data, and α_0, α_1, and d_j represent the constant, slope of first lag of the dependent variable without difference, and slope of lags of the dependent variable. The superscript *k* is the optimum

Table 1 Data variables and sources

Symbols	Variables	Measurement	Sources
LEX	Life expectancy	Life expectancy at birth, total (years)	WDI, 2022
CO_2	Carbon emissions	CO_2 emissions (metric tons per capita) used as a proxy for environmental degradation	WDI, 2022
PCI	Per capita income	GDP per capita (constant 2010 US$)	WDI, 2022
FPI	Food production index	Food production index (2004–2006 = 100)	WDI, 2022
POPG	Population growth	Population growth (annual %)	WDI, 2022
BR	Birth rate	Birth rate, crude (per 1000 people)	WDI, 2022
DR	Death rate	Birth rate, crude (per 1000 people)	WDI, 2022
IMF	Infant mortality rate	Mortality rate, infant (per 1000 live births)	WDI, 2022
HE	Health expenditure	Domestic general government health expenditure per capita (current US$)	WDI, 2022
INF	Inflation	Inflation, consumer prices (annual %)	WDI, 2022
EDU	Education	School enrollment, secondary (% gross) used as a proxy for education	WDI, 2022

Source: Authors' compilation

number of lags of the dependent variable. The variable is said to be stationary, if the coefficient α_1 value is smaller than one.

ARDL bounds testing

Equations 4 and 5 show the unrestricted error correction models used in the ARDL bounds test framework in terms of intercept or trend. In the framework described in both equations, the ARDL bounds cointegration test is carried out. These equations are estimated with ordinary least squares (OLS).

$$\Delta LY_t = a_0 + a_1 t + \sum_{i=1}^{m} \alpha_{2i} \Delta LY_{t-i} + \sum_{i=0}^{n} a_{3i} \Delta LX_{t-i} + a_4 LY_{t-1} + a_5 LX_{t-1} + \mu_{1t} \quad (4)$$

$$\Delta LX_t = \beta_0 + \beta_1 t + \sum_{i=1}^{m} \beta_{2i} \Delta LX_{t-i} + \sum_{i=0}^{n} \beta_{3i} \Delta LY_{t-i} + \beta_4 LX_{t-1} + \beta_5 LY_{t-1} + \mu_{2t} \quad (5)$$

Δ is the first difference operator and represents the residual term that is expected to be well behaved (serially independent, homoskedastic, and normally distributed). All coefficients are non-zero, except a_4 and β_4. Short- and long-term dynamic coefficients are represented by the parameters α_{2i} and a_{3i}, respectively. The a_0 and β_0 are drift components; μ_{1t} and μ_{2t} are white noise.

Johansen cointegration test

There are many methods for determining cointegration, such as the Engle and Granger (1987) test based on residuals and the Johansen (1991, 1992) test based on maximum likelihood. Many factors, such as economic crises, changes in institutional structures, policy shifts, regime shift war, and other drivers of structural change in developing economies necessitate that all variables be incorporated in the same order in these systems (Kim 2004; Perron 1989, 1997). The following equation summarizes the Johansen's cointegration test:

$$Z_t = AZ_{t-1} + \cdots + A_n Z_{t-n} + Bx_t + \epsilon_t \quad (6)$$

Variable x_t is the non-random variable in Eq. 6, while error correction term ϵ_t is part of the Zt independent and dependent variable vector. When dealing with tiny samples, Pesaran et al. (2001) devised the autoregressive distributive lag model (ARDL bounds testing technique to cointegration); no matter what sequence of integration is used, ARDL is still applicable.

Robustness analysis test

It is common in statistics to think that the empirical and normal distributions are asymptotically close to each other. The skewness and kurtosis statistical coefficients are used in the JB-test (Jarque and Bera 1980). The JB-test is defined as in Eq. 7 for N individuals:

$$\mathrm{JB} = \frac{N}{6}\left(W^2 + \frac{(K-3)^2}{4}\right) \quad (7)$$

where $W = \frac{\mu_3}{\mu_2^{3/2}}$ is the skewness $K = \frac{\mu_4}{\mu_2^2}$ is the kurtosis.

The study also calculated a bias adjusted LM statistic. The most widely used cross-sectional dependence diagnostic is the Lagrange multiplier (LM) test statistic (Breusch and Pagan 1979). Equation 8 for LM statistic for dependency is as follows under the null hypothesis:

$$LM = \sum_{i=1 j=i+1}^{N-1} \sum_{ij}^{N} \hat{\rho}_{ij}^2 \rightarrow \chi^2 \frac{N_{(N-1)}}{2} \quad (8)$$

Breusch-Pagan LM's standard test statistic is inadequate for testing in large populations, as has long been proven. According to Pesaran (2021), this issue may be solved by using an updated version of the LM statistic, as demonstrated in Eq. 9:

$$LM_S = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1 j=i+1}^{N-1} \sum_{ij} \left(T_{ij}\hat{\rho}_{ij}^2 - 1\right) \rightarrow N(0,1) \quad (9)$$

The conditional volatility exhibits a time-varying phenomena, which the ARCH test identifies. In Eq. 10, the ARCH effect may be traced back to time-varying conditional volatility.

$$\sigma_t^2 = E\left[\left(x_t - \bar{x}_t\right)^2\right] = E\left[x_t^2\right] - \bar{x}_t^2 \quad (10)$$

σ_t^2 is conditional variance and $\bar{x}_t$ is conditional mean.

Stability was ensured by using Ramsey RESET. The Ramsey regression equation specification error test (RESET) is a general linear regression model specification test. Nonlinear combinations of fitted values are tested to see if they help explain the response variable as mentioned in Eq. 11 (Ramsey 1969).

$$y = \alpha x + \gamma_1 \hat{y}^2 + \cdots + \gamma_{k-1} \hat{y}^k + \varepsilon \quad (11)$$

Granger causality analysis test

The linear model provided by Dumitrescu and Hurlin (2012) to assess panel causality is presented in Eq. 12:

$$Y_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_i^{(k)} Y_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(k)} X_{i,t-k} + \varepsilon_{i,t} \tag{12}$$

Discussion on empirical results

Descriptive statistics

Table 2 shows that the mean value of life expectancy, CO_2 emissions, per capita income, food production index, population growth, birth rate, death rate, infant mortality rate, health expenditure, inflation, and education is 4.12, − 0.40, 6.68, 4.32, 0.96, 3.57, 2.24, 4.48, 1.22, 2.01, and 3.28, respectively, while the standard deviation of life expectancy, CO_2 emissions, per capita income, food production index, population growth, birth rate, death rate, infant mortality rate, health expenditure, inflation, and education is 0.06, 0.33, 0.26, 0.45, 0.16, 0.15, 0.22, 0.27, 0.75, 0.49, and 0.30, respectively. Finally, the Jarque–Bera statistic accepts the null hypothesis of normal distribution, which shows that all variables are normally distributed except birth rate.

Unit root test results

Unit roots of all the series are tested by applying ADF and Zivot and Andrews (2002) structural break unit root test. The findings of the ADF test are given in Table 3. The variables CO_2 emissions, birth rate, death rate, and inflation are stationary at level, while life expectancy, per capita income, food production index, population growth, infant mortality rate, health expenditure, and education are stationary at first difference.

The findings of the Zivot and Andrews (2002) structural break unit root test are given in Table 4; the variables life expectancy (LEX), CO_2 emissions, per capita income, food production index, population growth, death rate, infant mortality rate, health expenditure, and inflation are stationary at level, while death rate is stationary after first difference. So there is a mixed order of data stationarity.

ARDL bounds testing

It is evident from Table 5 that the estimated value of the ARDL bound test, the lower and upper bound values are at 1% level of significance (2.41 and 3.61). So the *F*-statistic (459.8562) is greater than the upper bound, which supports the rejection of the null hypothesis of no cointegration among the variables (Pesaran et al. 2001).

Johansen cointegration test results

Table 6 further demonstrates that at a 1% level of significance, estimates of the Johansen cointegration test, both trace and eigen value test statistics suggest 10 cointegrated equations among the variables. The denial of H_0 that there is no cointegration is supported by both the Bounds and Johansen cointegration tests. Finally, both test statistics show that the variables have a long-term association.

Long-run and short-run ARDL estimation results

Table 7 shows the ARDL estimates where the coefficient of CO_2 emissions is negative which reveals that 1% rise the CO_2 emissions will reduce life expectancy by 0.046395%. Thus, environmental conditions like increased emissions of greenhouse gasses, poor air quality, air pollution, congestion, poor sanitation, lack of basic amenities, among others exert a considerable impact on the health outcomes. The finding are consistent with the finding of Ali and Audi (2016) and

Table 2 Descriptive statistics

	LEX	CO_2	PCI	FPI	POPG	BR	DR	IMR	HE	INF	EDU
Mean	4.12	− 0.40	6.68	4.32	0.96	3.57	2.24	4.48	1.22	2.01	3.28
Median	4.12	− 0.32	6.69	4.41	1.01	3.59	2.23	4.49	0.72	2.06	3.32
Maximum	4.21	− 0.01	7.11	4.97	1.21	3.74	2.61	4.88	2.77	3.03	3.80
Minimum	4.0	− 1.10	6.16	3.50	0.70	3.32	1.90	3.98	0.29	0.92	2.80
Std. Dev	0.06	0.33	0.26	0.45	0.16	0.15	0.22	0.27	0.75	0.49	0.30
Skewness	− 0.25	− 0.66	− 0.31	− 0.27	− 0.11	− 0.20	0.09	− 0.18	0.65	− 0.29	− 0.04
Kurtosis	1.93	2.23	2.22	1.78	1.53	1.39	1.64	1.77	2.04	2.54	1.77
Jarque–Bera	2.67	4.53	1.93	3.40	4.19	5.27	3.58	3.15	5.04	1.08	2.90
Probability	0.26	0.10	0.37	0.18	0.12	0.07	0.16	0.20	0.08	0.58	0.23
Sum	189.6	− 18.48	307.3	199.0	44.5	164.4	103.2	206.4	56.43	92.7	150.8
Sum Sq. Dev	0.16	5.11	3.07	9.29	1.28	1.10	2.26	3.29	25.56	11.18	4.11
Observations	46	46	46	46	46	46	46	46	46	46	46

Authors' estimation

Table 3 ADF test results

At level			1st difference		
Variables	Intercept	Intercept + trend	Variables	Intercept	Intercept + trend
Life expectancy (LEX)	2.965387	−0.903759	Δ(Life expectancy)	−0.371380	−4.035070*
CO_2 emissions (CO_2)	−3.859439*	−0.939288	Δ(CO_2 emission)	−7.621184*	−9.419689*
Per capita income	−1.455280	−2.276474	Δ(Per capita income)	−5.277877*	−5.335459*
Food production index	−2.094159	−0.827064	Δ(Food production index)	−7.478170*	−8.171321*
Population growth	−1.952539	−0.409682	Δ(Population growth)	−5.895655*	−4.215433**
Birth rate	−1.300061	−3.605220**	Δ(Birth rate)	−3.499147***	−5.243188*
Death rate	0.086333	−5.346535*	Δ(Death rate)	−2.060238	−1.884898
Infant mortality rate	2.965387	−0.903759	Δ(Infant mortality rate)	−0.371380	−4.035070*
Health expenditure	−0.231828	−2.177195	Δ(Health expenditure)	−8.778722*	−8.958689*
Inflation	−3.515441*	−3.367157**	Δ(Inflation)	−7.943220*	−7.833335*
Education	−0.397881	−2.956433	Δ(Education)	−6.875585*	−6.822200*

*, **, and *** indicate the significance level at 1%, 5%, and 10%, respectively

Table 4 Zivot and Andrews (2002) structural break unit root test

Variables	At level				1st difference			
	Intercept		Intercept + trend		Intercept		Intercept + trend	
	t-Stats	Break	*t*-Stats	Break	*t*-Stats	Break	*t*-Stats	Break
Life expectancy (LEX)	−5.234**	2001	−4.072	1989	−2.187**	2010	−3.301**	2003
CO2 emissions (CO2)	−2.013**	2008	−2.017	1990	−9.741**	2002	−9.668***	2003
Per capita income	−4.084*	1997	−3.731*	1997	−6.196**	1992	−6.228**	1992
Food production index	−2.658**	1986	−4.004***	1993	−8.633	1996	−8.915***	1995
Population growth	−1.596***	1999	−1.820***	2013	−1.393*	2012s	−1.493	1999
Birth rate	−4.242	2012	−6.070	1987	−1.185	1987	−2.576	1999
Death rate	−3.507	2012	−3.209**	2005	−3.815*	2006	−2.725	1993
Infant mortality rate	−2.177*	2014	−2.022	2004	−5.678*	1999	−4.846	1999
Health expenditure	−3.584	1983	−5.554*	2000	−9.369	1999	−9.292	1999
Inflation	−4.452***	2008	−4.502***	2008	−8.013	2003	−8.328***	2011
Education	−5.559*	2003	−5.914*	2003	−7.089	1992	−7.303***	1992

*, **, and *** indicate the significance level at 1%, 5%, and 10%, respectively

Table 5 Results of ARDL bound test

Test statistic	Value	Critical value		
		Significance	I(0), lower bound	I(1), upper bound
F-statistic	408.07831	10%	1.76	2.77
		5%	1.98	3.04
		1%	2.41	3.61

Null hypothesis: no long-run relationships exist

Rahman et al. (2022) and contrast with the findings by Ali and Ahmed (2014), Bayati et al. (2013) and Delavari et al. (2016). The coefficient of per capita income is also positive; it shows that 1% surge in the per capita income will raise the life expectancy by 0.001144%. Thus, when the per capita income of the people rises, the income of an individual or household is believed to affect health outcomes since higher levels of income permit increased expenditure in health optimizing activities, improved standards of living and housing conditions, adequate nutrition, access to, and consumption of high-quality goods and services which influence health positively. This result corroborates previous studies including Bayati et al. (2013), Sede and Ohemeng (2015), Luo and Xie (2020), and Wang et al. (2020). The estimated coefficient of food production index is negative which reveals that 1% rise in the food production index will reduce the life expectancy by 0.010727%; therefore, the Pakistani food quality is not good and mostly not nutrient. Further, the long-run ARDL estimates reveal that population growth has a positive effect on the life expectancy. More

Table 6 Results of Johansen cointegration test

Null hypothesis (H0)	Eigen values	Trace values		Max-eigen values	
		Statistics	Prob	Statistics	Prob
None	0.997503*	884.4073	0.0000	263.675*	0.0001
At most 1	0.981401*	620.7323	0.0000	175.325*	0.0000
At most 2	0.936580*	445.4074	0.0000	121.3508*	0.0000
At most 3	0.809845*	324.0565	0.0001	73.03639*	0.0000
At most 4	0.800104*	251.0201	0.0000	70.83824*	0.0000
At most 5	0.765686*	180.1819	0.0000	63.8481*	0.0006
At most 6	0.612682*	116.3338	0.0000	41.73438*	0.0002
At most 7	0.525050*	74.59942	0.0000	32.76*	0.0039
At most 8	0.408126*	41.83942	0.0000	23.07627*	0.0014
At most 9	0.347158*	18.76315	0.0000	18.76248*	0.0002
At most 10	1.53E−05	0.000675	0.9806	0.000675	0.9806

* indicates the significance level at 1%

Source: Authors' estimation

specifically, a 1% surge in the population growth will prolong the life expectancy by 0.008288 percentage points. The coefficient of birth rate has a positive effect on the life expectancy, which shows that 1% rise the birth rate will surge the life expectancy by 0.466607%. The positive sign of birth rate is not true theoretically; thus, a higher birth rate is expected to negatively affect the life expectancy. The coefficient of death rate is negative which reveals that 1% rise the death rate will reduce the life expectancy by 0.911756%. Thus, on the one hand, a low mortality rate indicates low population growth, and low population growth indicates a low reliance ratio and longer life expectancy, while on the other hand, a high death rate indicates a low dependency ratio and lower life expectancy. The coefficient of infant mortality rate is positive which reveals that 1% rise the infant mortality rate will surge the life expectancy by 0.178382%. A low infant mortality rate in a country leads to the high life expectancy.

Table 7 The ARDL estimates

Variables	Coefficient (Std. error)	*p* value
Long-run estimates		
Constant	3.731066* (0.00637)	0.0000
CO_2 emissions	−0.046395* (0.00500)	0.0007
Per capita income	0.001144 (0.00642)	0.8812
Food production index	−0.010727*** (0.00278)	0.0890
Population growth	0.008288** (0.21680)	0.0512
Birth rate	0.466607* (0.42432)	0.0000
Death rate	−0.911756* (0.06876)	0.0000
Infant mortality rate	0.178382* (0.00169)	0.0091
Health expenditure	0.000215** (0.00039)	0.0295
Inflation	−0.002072** (0.00425)	0.0354
Education	0.02002*** (0.00425)	0.0514
Short-run estimates		
Δ(CO_2 emissions)	−0.001037* (0.000186)	0.0000
Δ(Per capita income)	−0.00029 (0.000247)	0.2545
Δ(Food production index)	0.000169 (0.000175)	0.3452
Δ(Population growth)	−0.00284* (0.000157)	0.0000
Δ(Birth rate)	0.115826* (0.001089)	0.0000
Δ(Death rate)	−0.24211* (0.001464)	0.0000
Δ(Infant mortality rate)	−0.0174* (0.000682)	0.0000
Δ(Health expenditure)	−1.40E−05 (1.93E−05)	0.4762
Δ(Inflation)	3.78E−05* (9.43E−06)	0.0006
Δ(Education)	−4.55E−05 (5.50E−05)	0.4171
ECM(−1)	−0.028482* (0.000335)	0.0000

*, **, and *** indicate the significance level at 1%, 5%, and 10%, respectively

Selected Model: ARDL(1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 0). Regressand is life expectancy

Source: Authors' estimation

The coefficient of health expenditure is positive which reveals that 1% rise in the health expenditure will raise the life expectancy by 0.000215% (Table 6). Thus, people are spending more on their health-related concerns as their per capita health expenditure rises. Spending more on health-related concerns raises people's living standards and hence their life expectancy, as the same finding of Martín Cervantes et al. (2020) and Uddin (2021). The coefficient of inflation is positive and statistically significant, which indicates that a 1% increase in inflation will reduce the life expectancy by 0.002072%. The reason for the negative effect on life expectancy is that inflation affects health outcomes through the cost of health services. A high rate of inflation raises the cost of healthcare services, medications, and other health inputs, preventing people from using these services because they cannot afford them. This result is consistent with the finding of Ali and Ahmad (2014). The coefficient of education is positive which reveals that 1% rise in the education will raise the life expectancy by 0.02002%. Thus, people with a higher level of education are better able to cope with the adversity in life, and they are far more concerned with their health and a healthy lifestyle. These results are consistent with the findings of Ali and Ahmad (2014), Bayati et al. (2013), and Sede and Ohemeng (2015).

Table 6 also shows the short-run ARDL estimates. The short-run coefficient of CO_2 emissions, per capita income, population growth, death rate, health expenditure, and education have negative effect on the life expectancy. The examined results show that 1% surge in the CO2 emissions, per capita income, population growth, death rate, health expenditure, and education will reduce the life expectancy by 0.001037%, 0.00029%, 0.00284%, 0.24211%, 0.0174%, 1.40E – 05%, and 4.55E – 05%, respectively. Moreover, the coefficient of food production index, birth rate, and inflation have positive effect on the life expectancy. The examined results show that 1% surge in the food production index, birth rate, and inflation will raise the life expectancy by 0.000169%, 0.115826%, and 3.78E – 05%, respectively. The ECM coefficient value was found to support the theory (with a negative sign) and found 0.028482% annual convergence from short-run to long-run equilibrium for the selected variables.

ARDL diagnostic analysis

As shown in Table 8, ARDL diagnostic tests are used to investigate the life expectancy models' validity, reliability, and efficiency. Autocorrelation and heteroscedasticity are not a problem in the ARDL model, according to diagnostic tests. The Jarque–Bera and Ramsey RESET tests for model normality and stability are also used to determine whether the model is normally distributed and stable. The estimates show that the model is stable and normally distributed. Tests of the cumulative sum (CUSUM) and cumulative sum of square (CUSUMsq), which show the difference between long-run and short-run coefficients, also confirmed model stability. The dependability of policy replication based on the outcomes across the sample period is dependent on parameter stability. Because the red line comes between crucial boundaries (green and blue lines represent a 5% level of significance), both Figs. 1 and 2 depict that the life expectancy models (short-run and long-run) were adequately specified. This implied that both model parameters are devoid of flaws and generate consistent results.

Table 8 Robustness analysis

Test	*F* stats	Prob
Jarque–Bera test for normality	1.583498	0.4530
LM test for autocorrelation	3.673928	0.1209
ARCH test for heteroscedasticity	1.808006	0.1860
BPG-LM test for heteroscedasticity	0.967280	0.8585
Ramsey RESET test for stability	0.517359	0.4795

Robustness checks

We further employed FMOLS and DOLS to measure the robustness of the outcome of long-term estimates of the ARDL approach. The results of these two tests are illustrated in Table 9. As per the findings, there is a negative and significant long-term association between CO_2 emissions, food production index, death rate, and inflation have negative effect on life expectancy, while the per capita income, population growth, birth rate, infant mortality rate, health expenditure and education have positive effect on life expectancy. These experiments yielded identical results to the prior ones, demonstrating the consistency and robustness of ARDL technique findings.

Granger causality analysis test results

Granger causality analysis are given in Table 10. The estimates reveal that there is a bi-directional causality relationship between death rate and the life expectancy, death rate

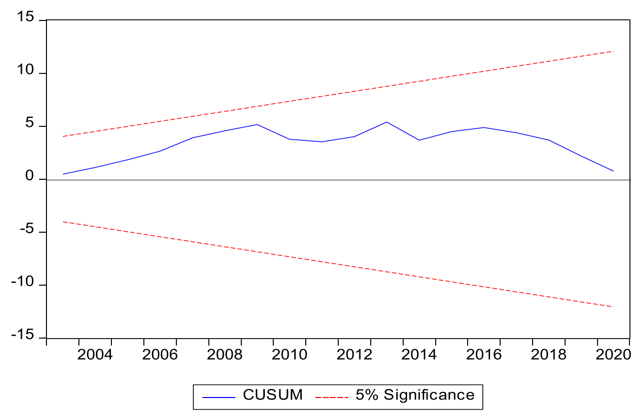

Fig. 1 The cumulative sum of the recursive residual plot

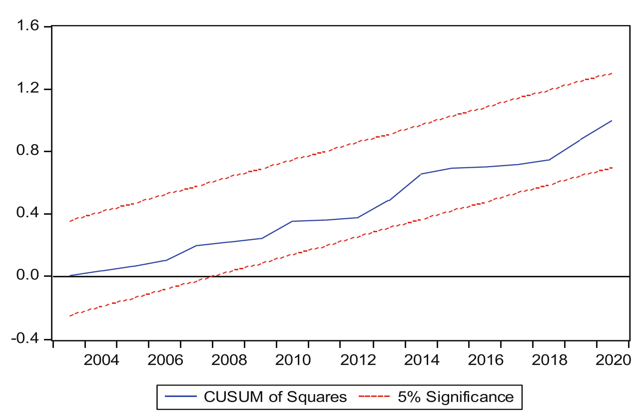

Fig. 2 The cumulative sum of the square of the recursive residual plot

and per capita income, death rate and birth rate, infant mortality rate and birth rate, health expenditure and death rate, education and CO_2 emissions.

Moreover, the estimates of Granger causality show that there are uni-directional causality exists between food production index and life expectancy, life expectancy and population growth, life expectancy and birth rate, life expectancy and infant mortality rate, life expectancy and education, inflation and per capita income, inflation and infant mortality rate, per capita income and food production index, per capita income and birth rate, per capita income and infant mortality rate, per capita income and health expenditure, per capita income and education, birth rate and food production index, death rate and food production index, food production index and health expenditure, food production index and CO_2 emissions, food production index and education, health expenditure and birth rate, CO_2 emissions and birth rate, education and birth rate, infant mortality rate and death rate, CO_2 emissions and death rate, education and death rate, health expenditure and infant mortality rate, education and infant mortality rate.

Furthermore, the estimates of Granger causality shows that there are no causality exists between population growth, inflation and birth rate, inflation and death rate, inflation and health expenditure, inflation and CO_2 emissions, education and inflation, per capita income and population growth, per capita income and CO_2 emissions, population growth and food production index, infant mortality rate and food

Table 9 Robustness checks

Variables	FMOLS		DOLS	
	Coefficient (Std. error)	*p* value	Coefficient (Std. error)	*p* value
Constant	4.293310* (0.028442)	0.0000	4.394068* (0.025671)	0.0000
CO_2 emissions	−0.007595** (0.003789)	0.0530	−0.013032** (0.004195)	0.0289
Per capita income	0.024526* (0.003106)	0.0000	0.019516*** (0.004693)	0.0532
Food production index	−0.006692** (0.002958)	0.0302	−0.014553** (0.002140)	0.0209
Population growth	0.00634* (0.001356)	0.0000	0.002284*** (0.000760)	0.0949
Birth rate	0.167738* (0.005698)	0.0000	0.165772* (0.009879)	0.0035
Death rate	−0.342165* (0.008157)	0.0000	0.378559* (0.007537)	0.0004
Infant mortality rate	0.029426* (0.004595)	0.0000	0.015604*** (0.002637)	0.0778
Health expenditure	0.001703* (0.000340)	0.0000	0.000372 (0.000358)	0.4076
Inflation	−0.000541* (0.000140)	0.0005	−0.001049** (0.000230)	0.0347
Education	0.002470* (0.000754)	0.0024	0.001664*** (0.000376)	0.0501
R^2	0.999911		0.999988	
Adjusted R^2	0.999885		0.999924	

*, **, and *** indicate the significance level at 1%, 5%, and 10%, respectively. Regressand is life expectancy

Source: Authors' estimation

Table 10 Granger causality test analysis

	LEX	INF	PCI	FPI	POPG	BR	DR	IMR	HE	CO_2	EDU
LEX	–	0.068	2.183	2.660***	17.73*	12.70*	8.933*	12.17*	1.820	1.209	4.954**
INF	1.004	–	6.034*	1.123	1.711	0.077	0.141	6.548*	0.180	1.002	1.314
PCI	1.055	0.445	–	4.341**	0.508	6.542**	3.813**	3.845**	0.968	1.195	7.179*
FPI	0.101	0.740	1.271	–	0.635	7.641*	7.780*	0.156	3.303**	1.535	0.620
POPG	0.752	0.279	1.155	0.017	–	1.128	1.129	1.660	1.509	0.296	0.750
BR	1.964	0.010	2.330	0.748	2.271	–	10.99*	6.062	4.539**	0.021	0.945
DR	2.577***	0.203	2.925***	0.044	1.907	12.99*	–	0.574	2.723***	0.151	3.253*
IMR	1.911	1.630	2.319	0.682	0.030	6.710*	2.426***	–	3.212***	1.171	6.704*
HE	1.376	0.269	3.739**	1.839	1.577	0.081	3.252**	0.231	–	0.904	0.601
CO_2	0.525	0.689	0.659	5.550*	1.058	5.026**	4.487**	0.312	1.171	–	2.639***
EDU	0.272	0.809	2.190	6.299	0.134	5.937*	1.040	0.792	2.012	5.371*	–

*, **, and *** indicate the significance level at 1%, 5%, and 10%, respectively

Source: Authors' estimation

production index, population growth and birth rate, population growth and death rate, population growth and infant mortality rate, population growth and health expenditure, population growth and CO_2 emissions, population growth and education, CO_2 emissions and infant mortality rate, CO_2 emissions and health expenditure, education and health expenditure.

Conclusion and policy recommendations

The main objective of this empirical study is to examine the impact of carbon emissions, per capita income, food production index, population growth, birth rate, death rate, infant mortality rate, inflation, and education on the life expectancy in Pakistan from 1975 to 2020. The unit root test reveals that all variables are of the mixed order of stationarity. As a result, we used the ARDL cointegration technique to quantify the concern variables' long-run and short-run elasticities. The long-run relationship between series is confirmed by the ARDL bound and Johansen cointegration tests. The long-run estimates of ARDL, FMOLS, and DOLS reveal that per capita income, population growth, birth rate, infant mortality rate, health expenditure, and education have a positive effect on the life expectancy, while inflation, food production index, death rate, and carbon emissions have a negative effect on the life expectancy. Moreover, the short-run estimates of ARDL reveal that per capita income, urbanization, population growth, health expenditure, and education have positive effect on the life expectancy, while inflation, food production index, death rate, infant mortality rate, and carbon emissions have negative effect on the life expectancy in Pakistan. Moreover, Granger causality results reveal that bi-directional causality exist between death rate and the life expectancy. Moreover, uni-directional causality exists between food production index and life expectancy, life expectancy and population growth, life expectancy and population growth, life expectancy and infant mortality rate, life expectancy and education.

The empirical findings of this study provide some policy recommendations for Pakistan to achieve long-term healthy population. Government intervention is needed to boost food production by giving subsidies to the agricultural sector, which would encourage farmers to produce more of the basic food grains that low-income people consume. Given that environmental pollution has a detrimental effect on the life expectancy, environmental pollution regulations must be adopted and implemented. It is equally important to invest in human resources to improve health. To enhance health outcomes, the government should prioritize the hiring of more trained health workers in the country's health sector. Moreover, macroeconomic stabilization measures must be implemented to contain growing costs, promote job possibilities, and aid the formation of small and medium-sized firms. Furthermore, individuals will be abled to afford proper nourishment, improve their living conditions, lower their reliance ratio, satisfy their health-care demands, and expand their revenue earning windows as a result. Policymakers needs to formulate policies that minimize carbon emissions and thereby promote public health and thereby productivity. Similarly, the budget allocation needs to be increased on health care to achieve the ultimate agenda of sustainable development and the well-being of the society.

Author contribution Muhammad Azam: conceptualization, methodology and software, formal analysis, conclusion, writing (original draft preparation), review, and editing.

Ijaz Uddin: conceptualization formal analysis, revised the manuscript, writing original draft preparation, review, and editing.

Najia Saqib: data curation, interpreted results, review, and editing.

Data availability Data used in this study for empirical examination have been obtained from the World Development Indicators (2022), The World Bank database. https://data.worldbank.org/.

Declarations

Ethics approval This study follows all ethical practices during writing and interpretations.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

Alemu AM (2017) To what extent does access to improved sanitation explain the observed differences in infant mortality in Africa? African J Prim Health Care Family Med 9(1):1–9

Ali A, Ahmad K (2014) The impact of socio-economic factors on life expectancy for sultanate of Oman: an empirical analysis. MPRA paper no. 70871. https://mpra.ub.uni-muenchen.de/id/eprint/70871

Ali A, Audi M (2016) The impact of income inequality, environmental degradation and globalization on life expectancy in Pakistan: an empirical analysis. MPRA paper no. 71112. https://mpra.ub.uni-muenchen.de/id/eprint/71112

Allen SH, Lektzian DJ (2013) Economic sanctions: a blunt instrument? J Peace Res 50(1):121–135

Azam M, Awan MA (2022) Health is wealth: a dynamic SUR approach of examining a link between climate changes and human health expenditures. Soc Indic Res. https://doi.org/10.1007/s11205-022-02904-x

Azam M, Khan F, Hafeez MH, Abdullah H (2019) Impacts of education and life expectancy on economic growth: some panel data evidence from developing economies. Pak J Soc Sci 39(4):1629–1639

Azam M, Ahmed MA (2015) Role of human capital and foreign direct investment in promoting economic growth: evidence from Commonwealth of Independent States. Int J Soc Econ 42(2):89–111

Azam M (2019) Relationship between energy, investment, human capital, environment and economic growth in BRICS-4. Environ Sci Pollut Res 26(33):34388–34400

Balan C, Jaba E (2011) Statistical analysis of the determinants of life expectancy in Romania. Roman J Regional Sci 5(2):25–38

Bayati M, Akbarian R, Kavosi Z (2013) Determinants of life expectancy in eastern Mediterranean region: a health production function. Int J Health Policy Manag 1(1):57–67

Bourne PA (2009) Inflation, public health care and utilization in Jamaica. Aust J Basic Appl Sci 3(3):3008–3024

Breusch ST, Pagan A (1979) A simple test for heteroscedasticity and random. Econometrica 47(5):1287–94

Burke M, Gong E, Jones K (2015) Income shocks and HIV in Africa. Econ J 125(585):1157–1189

CIHI (2016) Canadian Institute for Health Information. https://www.cihi.ca/en/healthsystem-performance/quality-of-care-and-outcomes/outcomes

Crimmins EM, Zhang YS (2019) Aging populations, mortality, and life expectancy. Ann Rev Sociol 45:69–89

Delavari S, Zandian H, Rezaei S, Moradinazar M, Delavari S, Saber A, Fallah R (2016) Life expectancy and its socioeconomic determinants in Iran. Electron Phys 8(10):3062

Dickey DA, Fuller WA (1979) Distribution of the estimators for autoregressive time series with a unit root. J Am Stat Assoc 74(366a):427–431

Dumitrescu EI, Hurlin C (2012) Testing for Granger non-causality in heterogeneous panels. Econ Model 29(4):1450–1460

Emamgholipour S, Asemane Z (2016) Effect of governance indicators on under-five mortality in OECD nations: generalized method of moments. Electron Phys 8(1):1747

Engle RF, Granger CW (1987) Co-integration and error correction: representation, estimation, and testing. Econometrica 251–276

Fayissa B, Gutema P (2005) Estimating a health production function for Sub-Saharan Africa (SSA). Appl Econ 37(2):155–164

Fayissa B, Gutema P (2005) The determinants of health status in Sub-Saharan Africa (SSA). Am Econ 49(2):60–66

Fayissa B, Gutema P (2008) A health production function for Sub-Saharan Africa (SSA). Working papers 200808, Middle Tennessee State University, Department of Economics and Finance.Avalaible at. https://ideas.repec.org/p/mts/wpaper/200808.html

Felice E, Andreu JP, D'Ippoliti C (2016) GDP and life expectancy in Italy and Spain over the long run: a time-series approach. Demogr Res 35:813–866

Garfield R (1997) The impact of economic embargoes on the health of women and children. J Am Med Women's Assoc (1972) 52(4):181–4

Grossman M (1972) On the concept of health capital and the demand for health. J Polit Econ 80(2):223–255

Haines A, Kovats RS, Campbell-Lendrum D, Corvalán C (2006) Climate change and human health: impacts, vulnerability and public health. Public Health 120(7):585–596

Hossain MS (2011) Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy 39:6991–6999

Imoughele LE, Ighata J, Obasanmi JO (2014) A quantitative analysis of determinants of health outcomes in Nigeria. Elite Res J Clin Pharm, Med Med Sci 2(3):17–24

Jarque CM, Bera AK (1980) Efficient tests for normality, homoscedasticity and serial independence of regression residuals. Econ Lett 6(3):255–259

Johansen S (1991) Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econometrica 1551–1580

Johansen S (1992) Cointegration in partial systems and the efficiency of single-equation analysis. J Econometrics 52(3):389–402

Kasman A, Duman YS (2015) CO_2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis. Econ Model 44:97–103

Kim H (2004) The measurement of international capital mobility using panel cointegration estimators. Seoul J Econ 17

Kim Y (2019) Economic sanctions and child HIV. Int J Health Plann Manage 34(2):693–700

Lind N (2021) Objective inequality indexes joining income with life expectancy through the life quality index of sub-populations. Soc Indic Res 153(3):781–794

Luo W, Xie Y (2020) Economic growth, income inequality and life expectancy in China. Soc Sci Med 256:113046

Mahalik MK, Le TH, Le HC, Mallick H (2022) How do sources of carbon dioxide emissions affect life expectancy? Insights from 68 developing and emerging economies. World Dev Sustain 100003. https://doi.org/10.1016/j.wds.2022.100003

Majeed MT, Ozturk I (2020) Environmental degradation and population health outcomes: a global panel data analysis. Environ Sci Pollut Res 27(13):15901–15911

Martín Cervantes PA, Rueda López N, Cruz Rambaud S (2020) Life expectancy at birth in Europe: An econometric approach based on random forests methodology. Sustainability 12(1):413. https://doi.org/10.3390/su12010413

Menon-Johansson AS (2005) Good governance and good health: the role of societal structures in the human immunodeficiency virus pandemic. BMC Int Health Hum Rights 5(1):1–10

Murthy U, Shaari MS, Mariadas PA, Abidin NZ (2021) The relationships between CO_2 emissions, economic growth and life expectancy. J Asian Finance, Econ Business 8(2):801–808

Nasreen S, Anwar S, Ahmad N (2012) Health status, income inequality and institutions: evidence from Pakistan economy. Pakistan J Life Soc Sci 10(2):139–144

Peksen D (2011) Economic sanctions and human security: the public health effect of economic sanctions. Foreign Policy Anal 7(3):237–251

Perron P (1989) The great crash, the oil price shock, and the unit root hypothesis. Econometrica 1361–1401

Perron P (1997) Further evidence on breaking trend functions in macroeconomic variables. J Econometrics 80(2):355–385

Pesaran MH (2021) General diagnostic tests for cross-sectional dependence in panels. Empirical Econ 60(1):13–50

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Economet 16(3):289–326

Pope CA III, Ezzati M, Dockery DW (2009) Fine-particulate air pollution and life expectancy in the United States. N Engl J Med 360(4):376–386

Raffin N, Seegmuller T (2014) Longevity, pollution and growth. Math Soc Sci 69:22–33

Rahman MM, Rana R, Khanam R (2022) Determinants of life expectancy in most polluted countries: exploring the effect of environmental degradation. PLoS ONE 17(1):e0262802

Ramsey JB (1969) Tests for specification errors in classical linear least-squares regression analysis. J Roy Stat Soc: Ser B (Methodol) 31(2):350–371

Razzak H, Ali M, Ali M (2015) Principal component analysis of socio-economic factors and their association with life expectancy at birth in Asia. Int J Multidiscip Acad Res 3(1):14–23

Razzaq A, Sharif A, Ahmad P, Jermsittiparsert K (2021a) Asymmetric role of tourism development and technology innovation on carbon dioxide emission reduction in the Chinese economy: fresh insights from QARDL approach. Sustain Dev 2021(29):176–193. https://doi.org/10.1002/sd.2139

Razzaq A, Sharif A, Najmi A, Tseng ML, Lim MK (2021b) Dynamic and causality interrelationships from municipal solid waste recycling to economic growth, carbon emissions and energy efficiency

using a novel bootstrapping autoregressive distributed lag. Resour Conserv Recycl 166:105372. https://doi.org/10.1016/j.resconrec.2020.105372
Salehnia, N., Karimi Alavijeh, N., & Hamidi, M. (2022). Analyzing the impact of energy consumption, the democratic process, and government service delivery on life expectancy: evidence from a global sample. Environ Sci Pollut Res 1-18. https://doi.org/10.1007/s11356-021-18180-0
Sapkota P, Bastola U (2017) Foreign direct investment, income, and environmental pollution in developing countries: panel data analysis of Latin America. Energy Econ 64:206–212
Saqib N (2018) Greenhouse gas emissions, energy consumption and economic growth: empirical evidence from Gulf Cooperation Council countries. Int J Energy Econ Policy 8:392–400. https://doi.org/10.32479/ijeep.7269
Saqib N (2022a) Nexus between the renewable and nonrenewable energy consumption and carbon footprints: evidence from Asian emerging economies. Environ Sci Pollut Res 1–15. https://doi.org/10.1007/s11356-022-19948-8
Saqib N (2022b) Green energy, non-renewable energy, financial development and economic growth with carbon footprint: heterogeneous panel evidence from cross-country. Econ Res-Ekonomska Istraživanja 1–20. https://doi.org/10.1080/1331677X.2022b.2054454
Saqib N (2022c) Asymmetric linkages between renewable energy, technological innovation, and carbon-dioxide emission in developed economies: non-linear ARDL analysis. Environ Sci Pollut Res 1-15. https://doi.org/10.1007/s11356-022-20206-0
Sharif A, Saqib N, Dong K, Khan SAR (2022) Nexus between green technology innovation, green financing, and CO2 emissions in the G7 countries: the moderating role of social globalisation. Sustain Dev 1–13. https://doi.org/10.1002/sd.2360
Sede PI, Ohemeng W (2015) Socio-economic determinants of life expectancy in Nigeria (1980–2011). Heal Econ Rev 5(1):1–11
Uddin I (2021) Impact of Benazir Income Support Program (BISP) on consumption, health and education. Economic Consultant 36:42–50. https://doi.org/10.46224/ecoc.2021.4.5
UNDP (2010) Human development report 2010: The real wealth of nations: Pathways to human development. New York
Wagstaff A (1986) The demand for health: theory and applications. J Epidemiol Commun Health 40(1):1–11
Wang S, Ren Z, Liu X, Yin Q (2022) Spatiotemporal trends in life expectancy and impacts of economic growth and air pollution in 134 countries: a Bayesian modeling study. Soc Sci Med (1982) 293:114660
Wang Z, Asghar MM, Zaidi SAH, Nawaz K, Wang B, Zhao W, Xu F (2020) The dynamic relationship between economic growth and life expectancy: contradictory role of energy consumption and financial development in Pakistan. Struct Chang Econ Dyn 53:257–266
World Development Indicators (2022) World Bank. http://databank.worldbank.org
World Health Organisation: Sanitation, key facts. Online publication: WHO; 2019. https://www.who.int/news-room/fact-sheets/detail/sanitation. Accessed on 2 June 2020.
World Health Organization (2014) Aging well must be a global priority. World Health Organization, Geneva, November 6, 2014
World Health Organization: Ambient air pollution: health impacts. Department of Public Health, Environmental and Social Determinants of Health (PHE). Geneva:WHO;2018. https://www.who.int/airpollution/ambient/health-impacts/en/. Accessed on 29th May 2020.
Yang H, Wang S, Ren Z, Liu H, Tong Y, Wang N (2022a) Life expectancy, air pollution, and socioeconomic factors: a multivariate time-series analysis of Beijing City, China. Soc Indicators Res 1-16. https://doi.org/10.1007/s11205-021-02872-8
Yang Q, Huo J, Saqib N, Mahmood H (2022b) Modelling the effect of renewable energy and public-private partnership in testing EKC hypothesis: evidence from methods moment of quantile regression. Renew Energy 192:485–494. https://doi.org/10.1016/j.renene.2022.03.123
Zafar A, Majeed MT, Nosheen M, Iqbal J (2021) Globalization, financial development, and environmental sustainability: evidence from heterogenous income groups of Asia. Environ Sci Pollut Res 28(36):50430–50446
Zhang J, Liu Y, Saqib N and Waqas Kamran H (2022) An empirical study on the impact of energy poverty on carbon intensity of the construction industry: moderating role of technological innovation. Front Environ Sci.https://doi.org/10.3389/fenvs.2022.929939
Zivot E, Andrews DWK (2002) Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. J Business Econ Stat 20(1):25–44. https://doi.org/10.1016/j.rser.2016.10.018

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.